Study of Spectral Efficiency in Massive MIMO

Dr.Ch.Vijay[1], Srikanth Karingana[2], VVS Varshitha Kuncha[3], Divya Mamidi[4], Deva Namala[5]
[1]*Assistant Professor, Department Of Electronics and Communication Engineering, Raghu Institute of Technology, Andhra Pradesh, India*
[2,3,4,5] *UG Student, Department Of Electronics and Communication Engineering, Raghu Institute of Technology, Andhra Pradesh, India*

***Abstract*— Massive MIMO is a promising technique to increase the spectral efficiency (SE) of cellular networks, by deploying antenna arrays with hundreds or thousands of active elements at the base stations and performing coherent transceiver processing. A common rule-of- thumb is that these systems should have an order of magnitude more antennas, M, than scheduled users, K, because the users' channels are likely to be near- orthogonal when M/K > 10. Monte Carlo estimation technique is used to estimate the possible outcomes. P- ZF, ZF, MR are the conventional linear processing schemes used. Spectral efficiency and number of base station antennas are considered for the study of performance of Massive MIMO systems. From the study it is observed that pilot zero forcing gives better performance when compared to other techniques.**

***Index Terms:* OFDM, MIMO-OFDM, SE, Zero Forcing, Pilot Zero Forcing, Maximum Ratio, SINR.**

I.INTRODUCTION

Cellular networks are continuously developing to keep up the rapidly increasing demand for wireless data communication. In before days to send one mb of data it will take more time but now a days we can send 100mb data with in no time. This can be only be possible with the higher area throughput, it has been achieved by a combination of three factors : high frequency spectrum, higher cell density, and higher spectral efficiency .

So in this we are going to consider spectral efficiency, so that by considering the three different schemes ZF, PZF, MR and going to observe in which scheme we can get the maximum SE.

We are considering the massive multiple-input multiple-output (MIMO) concept, which has been identified as the key source to increase the spectral efficiency (SE). The massive MIMO is a concept based on equipping hundreds and thousands of Base Station (BS) antenna elements that can provide unprecedented array gains and a spatial resolution that allows for multi-user MIMO communication to tens or hundreds of user equipment (UEs).

There are different forms of antenna technology that refer to single or multiple input and outputs. We are considering the Massive MIMO (Multi Input Multi Output).In general the MIMO will be having multiple number of antennas in input side and output side so as we are considering the massive MIMO which is an extension of MIMO technology which are using hundreds and even thousands of antennas that are attached to a base station to improve spectral efficiency and also throughput.

Spectral efficiency or bandwidth efficiency is the amount of data transmitted over a given spectrum with minimum number of transmission errors.

II.AREA CONSIDERATIONS AND PARAMETERS FOR MASSIVE MIMO SYSTEMS

We have considered cellular networks having the universal time and frequency, where the base station is equipped with an array of M antennas and communicates with K single antenna User Equipment at a time.

We have considered the area of the hexagonal region which is having the symmetric network topology. The cell radius is denoted by $r > 0$ and is the distance from the cell center to the corners.

For this process to find the SE we need to take some considerations ,they are

- How many UE's should be scheduled per cell to maximize SE ? (K)
- No. of Antenna 's (M)
- Hardware impairments

So we are doing simulation according to the above taken considerations.

SIGNAL TO INTERFERENCE NOISE RATIO (SINR):

This SINR will gives the signal quality as the strength of wanted signal to the unwanted signal. So we have taken this SINR into consideration for getting the wanted signal. And the equation is :

$$\mathrm{SINR}_{jk}^{(\mathrm{ul})} = \frac{p_{jk}|\mathbb{E}_{\{\mathrm{h}\}}\{\mathrm{g}_{jk}^{\mathrm{H}}\mathrm{h}_{jjk}\}|^2}{\sum_{l\in\mathcal{L}}\sum_{m=1}^{K} p_{lm}\mathbb{E}_{\{\mathrm{h}\}}\{|\mathrm{g}_{jk}^{\mathrm{H}}\mathrm{h}_{jlm}|^2\} - p_{jk}|\mathbb{E}_{\{\mathrm{h}\}}\{\mathrm{g}_{jk}^{\mathrm{H}}\mathrm{h}_{jjk}\}|^2 + \sigma^2\mathbb{E}_{\{\mathrm{h}\}}\{\|\mathrm{g}_{jk}\|^2\}}.$$

ASYMPTOTIC LIMIT:

This is the maximum limit of spectral efficiency that which the quality of signal can be measured and its equation is as follows:

$$\mathrm{SE}_j^{\infty} = K\left(1 - \frac{K\beta}{S}\right)\log_2\left(1 + \frac{1}{\sum_{l\in\mathcal{L}_j(\beta)\setminus\{j\}}\mu_{jl}^{(2)}}\right)$$

CONVENTIONAL LINEAR PROCESSING SCHEMES:

We considered the conventional linear processing schemes they are the zero forcing (ZF) and the maximum ratio (MR) and a fully pilot-zero forcing (P- ZF).These schemes will actively suppress the inter- cell interference. So we observing these three schemes output we can decide in which scheme the maximum SE is obtaining.

III.PROPAGATION ENVIRONMENT

We are simulating the spectral efficiency in a cell on a hexagonal grid and taking into consideration as there exists an interference in the cell .And the user equipment can be anywhere in the cell but they should be at least 0.14r from the serving base station.

These linear processing schemes are used in the both the directions. The simulations consider the maximum ratio (MR), zero forcing (ZF) and pilot zero forcing(PZF) and the results are obtained using the expression as above discussed. The simulations are performed using the Matlab that enables to simple testing of other parameter values.

For each and every number of antennas as M,we are optimizing the spectral efficiency with respect to the user equipment number as K by searching all the reasonable integer values.

So we are considering the three propagation environments with the different severity of the interference with in the inter cell. And these are divided as cases as follows:

Case-1: Average of uniform User Equipment locations in all cells

Case-2 : All the user equipment in the other cells are at the cell edge and the furthest from base station

Case-3 : All the user equipment in the other cells are at the cell edge and the closest to base station

IV. RESULTS

By changing these parameters in the code simulation is done and the results are obtained which are shown in the next page.

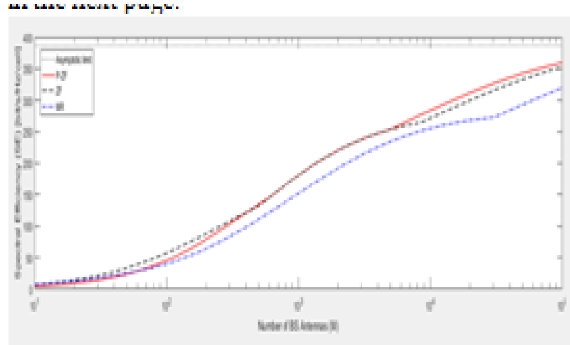

Fig.1 Simulation for average case of inter-cell interference

The above figure is the result obtained for the case-1 which is assumed as the average of uniform User Equipment locations in all cells. By observing the above graph it is plotted with number of base stations as x-axis and the optimal number of scheduled user equipment in y-axis. So the dotted is the asymptotic limit and from graph we can observe only the PZF is very close to the asymptotic limit and ZF is somewhat farther than the PZF and the MR is very far from the limit. So we can consider the PZF scheme can obtain maximum SE in this case.

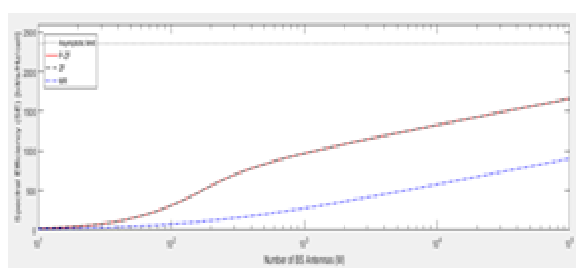

Fig.2 Simulation for best case of inter-cell interference

The above figure is the result obtained for the case-2 which is assumed as the all the user equipment in the other cells are at the cell edge and the furthest from base station.By observing the above graph it is plotted with number of base stations as x-axis and the optimal number of scheduled user equipment in y-axis.So the dotted is the asymptotic limit and from graph we can observe the PZF and the ZF are on the same the line and close to the asymptotic limit and MR is very far from the asymptotic limit.

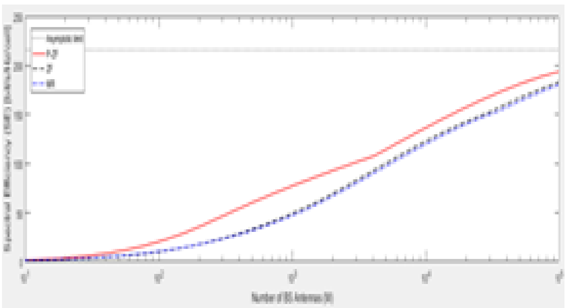

Fig.3 Simulation for worst case of inter-cell interference

The above graph is obtained after changing the parameter values for case-3 and observing the graph. From the graph we can see after changing the values the asymptotic limit is increased and as usual the PZF is near to the asymptotic limit and remaining are far from the asymptotic limit.

So after observing these graphs we named them as follows:

Case-1 : Average case

Case-2: Best case

Case-3: Worst case

So the best case can be overly optimistic because the user equipment positions in the interfering cells are different with respect to the different cells. And in the worst case can be overly pessimistic because the user equipment can't be in a worst locations with respect to all the cells. And the average can be practically applicable because we have taken the average of user equipment locations.

Hardware Impairments:

Now the simulation results for the hardware impairments. As till now we have simulated for the ideal transceivers that the signal will not have any type of distortions but in practical there exists imperfections in the medium that causes the distortions of signal. So below graph is the simulation result of hardware impairments.

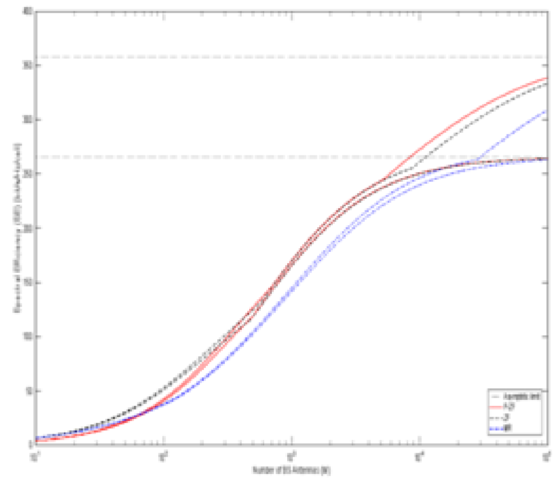

Fig.4 Simulation for Hardware impairments existence

Above figure is the graph of hardware impairments. The graph is plotted between the number of base station antenna (M) vs the spectral efficiency. We have taken the ϵ = 0 for the ideal transceivers which means there will be no distortions and ϵ = 0.1 which there exists distortions. So while observing the graph the hardware impairments seems to have a small impact on the practical massive mimo systems.

Selected number of user equipment(K):

We also simulated the selected number of user equipment(K) to know the performance. So we have taken the selected number as K=10.

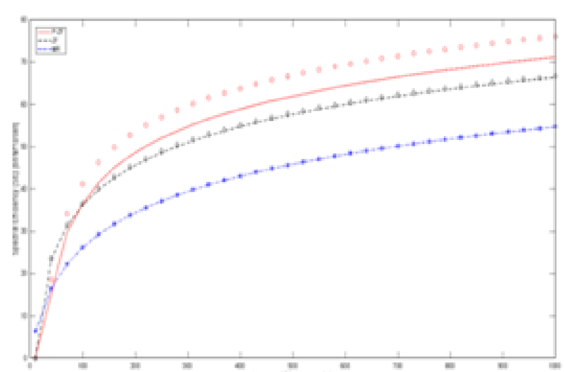

Fig.5 Simulation for Selected number of user equipment(K=10)

Above figure is the graph of the selected number of user equipment(K).The graph is plotted between the number of base station antennas(M) and spectral efficiency.

V. CONCLUSION

In this study, we have observed how many user equipments (K), that should be scheduled in a massive MIMO systems to get maximum SE per cell for a fixed number of base station antennas(M).We had applied symmetric network topologies, where each cell is represent table for any cell, these conventional linear schemes can directly provide the network-wide performance. From the results we have observed that P-ZF gives the highest performance per UE ,MR gives the lowest spectral efficiency per UE. And in contrast, MR schedules the largest number of UEs and P-ZF the smallest number.

Finally by using the fully pilot zero forcing we are able to get the maximum spectral efficiency.

REFERENCES

[1] Nokia Siemens Networks, “2020: Beyond 4G radio evolution for the Gigabit experience,” White Paper, Tech. Rep., 2011.

[2] T. L. Marzetta, “Noncooperative cellular wireless with unlimited numbers of base station antennas,” IEEE Trans. Wireless Commun., vol. 9, no. 11, pp. 3590–3600, Nov. 2010.

[3] R. Baldemair, E. Dahlman, G. Fodor, G. Mildh, S. Parkvall, Y. Selen, ´ H. Tullberg, and K. Balachandran, “Evolving wireless communications: Addressing the challenges and expectations of the future,” IEEE Veh. Technol. Mag., vol. 8, no. 1, pp. 24–30, Mar. 2013.

[4] F. Boccardi, R. Heath, A. Lozano, T. Marzetta, and P. Popovski, “Five disruptive technology directions for 5G,” IEEE Commun. Mag., vol. 52, no. 2, pp. 74–80, Feb. 2014.

[5] E. G. Larsson, F. Tufvesson, O. Edfors, and T. L. Marzetta, “Massive MIMO for next generation wireless systems,” IEEE Commun. Mag., vol. 52, no. 2, pp. 186–195, Feb. 2014.

[6] J. Jose, A. Ashikhmin, T. L. Marzetta, and S. Vishwanath, “Pilot contamination and precoding in multi-cell TDD systems,” IEEE Trans. Commun., vol. 10, no. 8, pp. 2640–2651, Aug. 2011.

[7] J. Hoydis, S. ten Brink, and M. Debbah, “Massive MIMO in the UL/DL of cellular networks: How many antennas do we need?” IEEE J. Sel. Areas Commun., vol. 31, no. 2, pp. 160–171, Feb. 2013

[8] H. Q. Ngo, E. G. Larsson, and T. L. Marzetta, “Energy and spectral efficiency of very large multiuser MIMO systems,” IEEE Trans. Commun., vol. 61, no. 4, pp. 1436–1449, Apr.2013.

[9] E. Bjornson, L. Sanguinetti, J. Hoydis, and M.Debbah, “Optimal design of energy-efficient multi-user MIMO systems: Is massive MIMO the answer?” IEEE Trans. Wireless Commun., vol. 14, no. 6, pp. 3059–3075, Jun. 2015.

[10] D. Ha, K. Lee, and J. Kang, “Energy efficiency analysis with circuit power consumption in massive MIMO systems,” in Proc. IEEE Int. Symp. Personal, Indoor and Mobile Radio Commun. (PIMRC), 2013.

[11] H. Yang and T. Marzetta, “Total energy efficiency of cellular large scale antenna system multiple access mobile networks,” in Proc. IEEE Online Conference on Green Communications (Online GreenComm), 2013.

[12] E. Bjornson, J. Hoydis, M. Kountouris, and M. Debbah, “Massive ¨ MIMO systems with non-ideal hardware: Energy efficiency, estimation, and capacity limits,” IEEE Trans. Inf. Theory, vol. 60, no. 11, pp. 7112– 7139, Nov. 2014.

[13] E. Bjornson, M. Matthaiou, and M. Debbah, “Massive MIMO with ¨ arbitrary non-ideal arrays: Hardware scaling laws and circuit-aware design,” IEEE Trans. Wireless Commun., vol. 14, no. 8, pp. 4353–4368, Aug. 2015.

[14] A. Pitarokoilis, S. K. Mohammed, and E. G. Larsson, “Uplink performance of time-reversal MRC in massive MIMO systems subject to phase noise,” IEEE Trans. Wireless Commun., vol. 14, no. 2, pp. 711–723, Feb. 2015.

[15] H. Huh, G. Caire, H. Papadopoulos, and S. Ramprashad, “Achieving “massive MIMO” spectral efficiency with a not-so-large number of antennas,” IEEE Trans. Wireless Commun., vol. 11, no. 9, pp. 3226– 3239, Sept. 2012.

[16] M. Li, Y.-H. Nam, B. Ng, and J. Zhang, “A non-asymptotic throughput for massive MIMO cellular uplink with pilot reuse,” in Proc. IEEE Globecom, 2012.

[17] R. Muller, M. Vehkaper ¨ a, and L. Cottatellucci, “Blind pilot decontami- ¨ nation,” in Proc. WSA, 2013.
[18] H. Yin, D. Gesbert, M. Filippou, and Y. Liu, “A coordinated approach to channel estimation in large-scale multiple-antenna systems,” IEEE J. Sel. Areas Commun., vol. 31, no. 2, pp. 264–273, Feb. 2013.
[19] M. Li, S. Jin, and X. Gao, “Spatial orthogonality-based pilot reuse for multi-cell massive MIMO transmission,” in Proc. WCSP, 2013.
[20] M. Karlsson and E. G. Larsson, “On the operation of massive MIMO with and without transmitter CSI,” in Proc. IEEE SPAWC, 2014.
[21] X. Gao, O. Edfors, F. Rusek, and F. Tufvesson, “Massive MIMO performance evaluation based on measured propagation data,” IEEE Trans. Wireless Commun., vol. 14, no. 7, pp. 3899–3911, July 2015.
[22] K. Guo, Y. Guo, G. Fodor, and G. Ascheid, “Uplink power control with MMSE receiver in multi-cell MU-massive-MIMO systems,” in Proc. IEEE ICC, 2014.
[23] H. Yang and T. Marzetta, “A macro cellular wireless network with uniformly high user throughputs,” in Proc. IEEE VTC-Fall, 2014.
[24] M. Biguesh and A. B. Gershman, “Downlink channel estimation in cellular systems with antenna arrays at base stations using channel probing with feedback,” EURASIP J. Appl. Signal Process., vol. 2004, no. 9, pp. 1330–1339, 2004.
[25] M. Medard, “The effect upon channel capacity in wireless communications of perfect and imperfect knowledge of the channel,” IEEE Trans. Inf. Theory, vol. 46, no. 3, pp. 933–946, May 2000.
[26] B. Hassibi and B. M. Hochwald, “How much training is needed in multiple-antenna wireless links?” IEEE Trans. Inf. Theory, vol. 49, no. 4, pp. 951–963, Apr. 2003.